

EFFECTS OF THE TSUNAMI IN THE CHAGOS ARCHIPELAGO

BY

CHARLES R. C. SHEPPARD¹

ABSTRACT

The five atolls and numerous submerged atolls and banks of the Chagos Archipelago are all separated from each other by very deep water, and there are no broad or gently shallowing shelves between the atolls and the site of origin of the December 2004 tsunami. Effects of the recent tsunami in Chagos were mixed. The vegetation of some islands has been damaged in places, but nowhere very extensively. Following an inspection of many islands in all 5 atolls in February 2005, it was clear that the results of the tsunami must be looked at in the context of the shoreline erosion that is taking place in these islands. It appears likely that the tsunami accelerated coastal erosion by 1-2 years on eastern sides at least. Almost all damage seen on land was on eastern sides, where undergrowth vegetation was stripped away in several places, leaving only mature palms.

In the sublittoral, most of these eastern areas had low cover by stony and soft corals, but this was also the case in 1999 and 2001 when coral and soft coral cover was drastically reduced, whose cause was attributed to the 1998 mass mortality. Most areas which now have low benthic cover used to be dominated by soft rather than hard corals; soft corals have shown poor recovery to date in any location in this archipelago. Most western facing seaward reefs previously dominated by stony corals show stronger coral recovery from 1998 than do most eastern facing seaward locations. However, some western facing seaward slopes on Diego Garcia still show very low cover, as was the case in 1999 and 2001. There is no consistent pattern to suggest that the tsunami had any widespread sublittoral impacts, and present coral and soft coral cover appears to be much more strongly determined by the legacy of 1998 and differential recruitment of benthic groups.

Substantial movement of sand was observed on eastern and southern Salomon atoll, and shoreline erosion was marked in many places in all atolls. Refraction around atolls was minimal such that, with one exception, no damage was seen on western sides of atolls.

¹Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, UK.
Email: charles.sheppard@warwick.ac.uk

INTRODUCTION

The Chagos Archipelago lies just south of the equator in the central Indian Ocean (Fig. 1). It consists of five islanded atolls and at least the same number of awash and submerged atolls and banks, extending over a roughly circular area of diameter >300 km. Its total land area, however, is only about 53 km², with another 82 km² of reef flats and awash substrate. Of the land area, about half lies in the main island of the southernmost atoll Diego Garcia (2720 ha), which is one of the most enclosed atolls in the world containing deep (>30m) water within its lagoon. One atoll, the Great Chagos Bank, has commonly been described as the world's largest atoll, being approximately 200 km in an East-West direction, though this supports islands only on its western and northern sides. One of its islands, Eagle Island, is the second largest, at 243 ha. Thus the atolls differ markedly in character (Table 1).

Submerged atolls lie around, and in one case between, the islanded atolls. This includes Blenheim, which dries at low tide, and others (e.g. Pitt, Victory, Speakers) whose shallowest surfaces lie variously between 5 and 11 m depth

Bathymetry

Of particular relevance in the present context is the bathymetry of the region. Unlike the Maldives immediately to the north, most of whose atolls lie in a 'double chain' in relatively shallow water, all atolls, submerged atolls and banks in Chagos are separated from others by deep water, mostly 1-2 km deep (see the inset in Figure 1 which shows the 1000 m contours in Chagos). Deep water lies between Chagos and Sumatra (Fig. 2).

Within the archipelago, the proportion of substrate of different depths has been accurately computed (Dumbraveanu and Sheppard 1999) using GIS from all published bathymetric charts of atolls, banks and of the total archipelago. The quantity of substrate estimated is considerably greater than those given in some earlier estimates. While the seaward reefs of each atoll have the classical form of a reef flat at sea level, followed by a gentle slope to a 'drop-off' at about 10-15 m, followed by a steeper slope, there are interesting patterns in the depth distribution of substrate. For example, a simplified extract for depths less than 100 m depth (Fig. 3) reveals a greater proportion of substrate between 20-40 m than 40-70 m depth, and there is another increase of surface area between 70-90 m depth. In these atolls, peak coral diversity lies at 20 m depth, which is deeper than that recorded for most reef systems (Sheppard 1980). This was attributed to the high water clarity and appeared not to be influenced by the location of the drop-off.

Island Erosion

With sea level rising slowly but steadily (Woodworth et al., 2004), and following the warming that occurred in 1998 which caused massive coral mortality in Chagos (Sheppard et al., 2002), the erosion that has been taking place in these shores for many years is accelerating. Elevation transects measured across several islands in these atolls (Sheppard, 2002) show that the centres of many islands lie close to, or even below, high

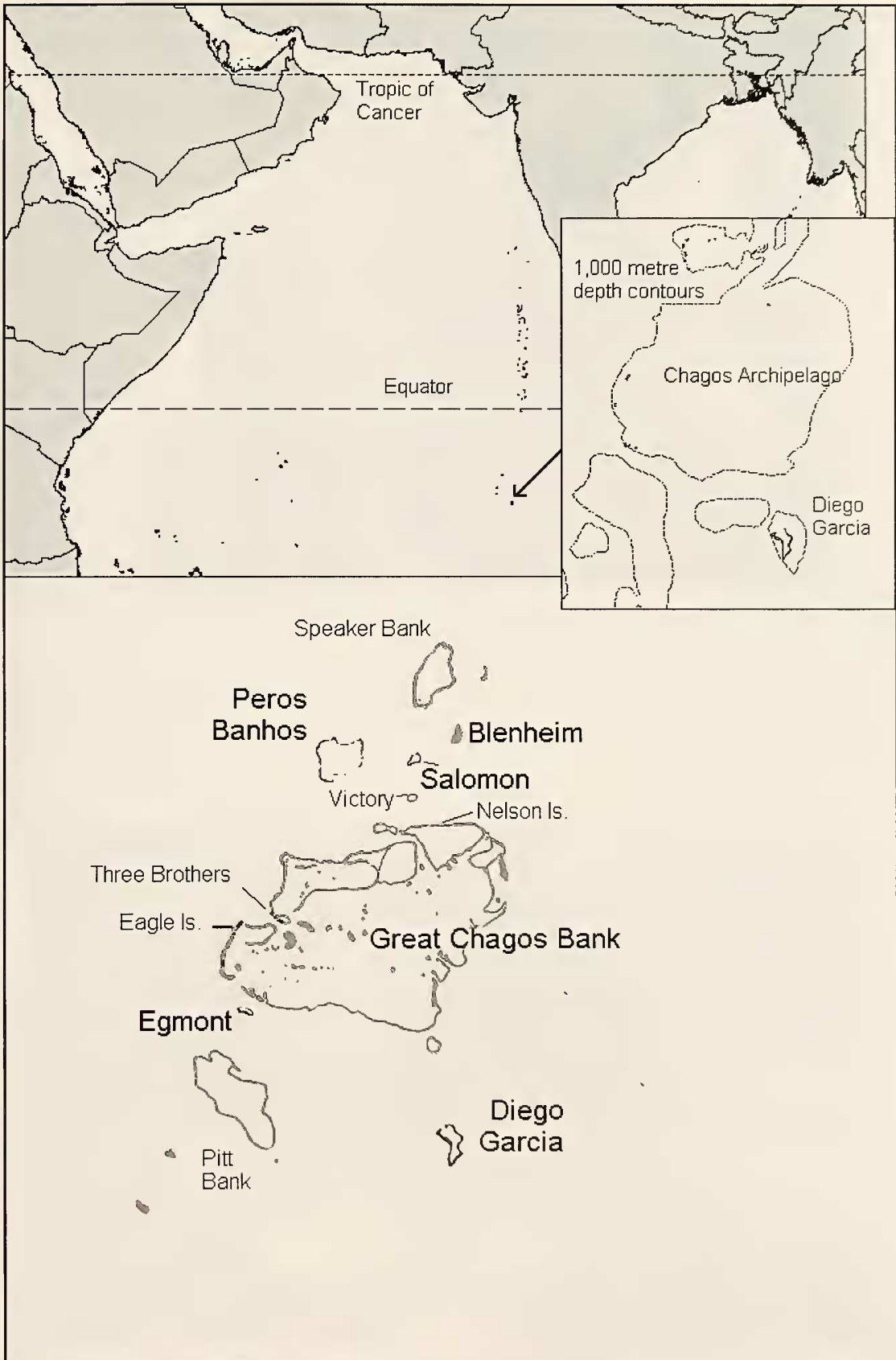


Figure 1. Location map of the Chagos Archipelago.

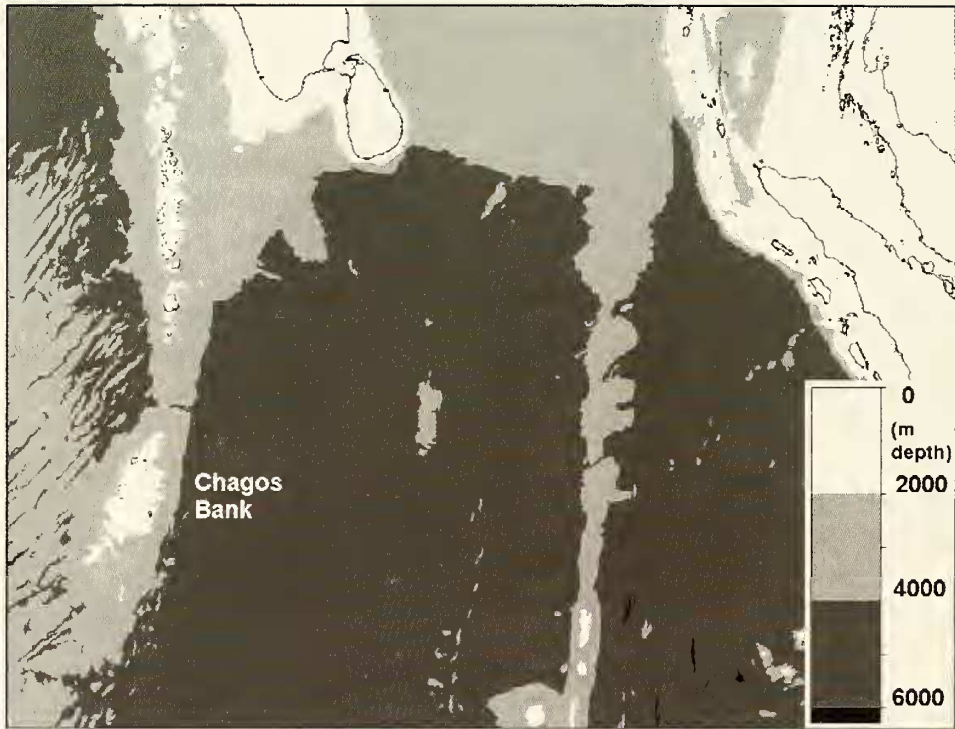


Figure 2. Bathymetry of the Indian Ocean between Chagos and the tsunami site of origin. Taken from GEBCO Digital Atlas (2003). Depth spans are 2000 m depth.

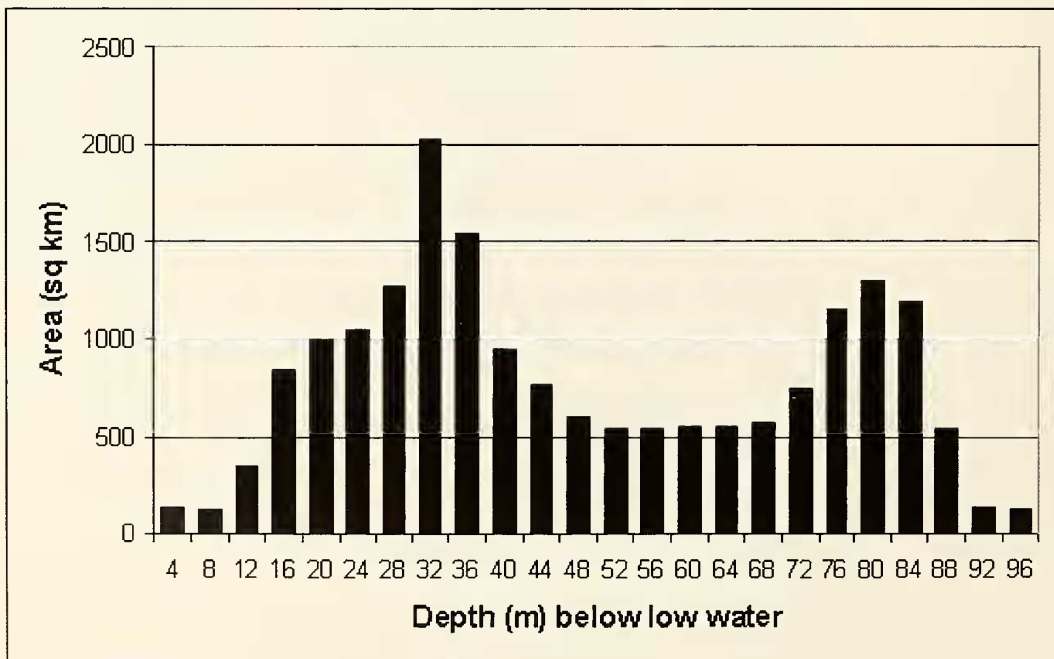


Figure 3. Distribution of areas of different depth spans in the Chagos Archipelago (to 100 m only). On x-axis, each bar indicates the span *to* that depth *from* the shallower depth to its left. From Dumbraveanu and Sheppard (1999).

tide level. They do not usually flood with seawater because each has a raised rim around its perimeter which, quite simply, acts as a dam to water and wave encroachment. That, together with a very high rainfall (Table 1) has been clearly sufficient to maintain persistent fresh water lenses within almost all islands.

Table 1. Areas and physical characteristics of the 5 islanded atolls of Chagos. Rainfall data from Stoddart (1971).

Atoll	Latitude at centre	Atoll area Km ²	Land area (Ha)	No. islands	% rim enclosed by islands	% rim enclosed by islands and reef flats	Max lagoon depth (m)	Raised reef present	Rainfall mm y ⁻¹
Peros Banhos	5° 20'	463	953	31	30	65	66	Yes	3 999
Salomon	5° 20'	38	263	11	50	85	30	No	3 751
Great Chagos Bank	6° 10'	18 000	437	8	>2	>5	88	Yes	
Egmont	6° 40'	48	401	3	30	95	17	No	
Diego Garcia	7° 20'	250	2734	5	95	97	32	No	2 599

Erosion is now very evident in many places around many of the islands, and while this has continued progressively for many years it appears to have been accelerating over the last 8 years (scientific visits recommenced in 1996 after a gap of 17 years). Around much of the northern tip of Diego Garcia the erosion is striking; substantial shore defence has been put in place to stop further attrition (Fig. 4).



Figure 4. Northern tip of western Diego Garcia showing concrete armouring against erosion. The reef flat at this site is over 100 m wide. View looking North.

Further south, where a recreational club existed on the western side, there were steps leading down to the beach; now that shoreline is well eroded and the steps have disintegrated. By early 2006, most of the sand had disappeared from large stretches, exposing the underlying limestone. Further south still, the protective rim is now only about a metre wide in places and already some small plumes of beach sand are being pumped through onto the road at high tides (Fig.5).



Figure 5. Erosion of the seaward side of the western arm of Diego Garcia. The observer is standing on the high tide level, the thin rim behind him is now all that stops inundation of the road at this point.

On other atolls there are no fixed structures against which erosion has been measured, but familiarity with several locations shows similar patterns. Therefore, erosion by the sea has been a continuing and accelerating process, one which is not caused only by storms and tsunamis but by every high tide, especially spring tides. The process is being forced faster by rising sea levels. The present brief survey results must be considered against this background.

RESULTS

Direct Damage on Islands

Reports by residents on the day of the tsunami are largely limited to their observations of several large ‘tidal cycles’ occurring in the lagoon of Diego Garcia during the course of the morning, and of considerable terrestrial debris (palm fronds etc.) being transported along the shorelines. The residents are all located on the western and

therefore sheltered arm of Diego Garcia atoll, and apparently there were no observed instances of damage in that region. Some visitors on yachts anchored in Salomon lagoon further north reported similar unusual tidal movements and swirling of water, but no serious consequences.

The islands were visited in February 2005. Observations of spectacular damage were few. On Diego Garcia's eastern arm, large waves clearly smashed through the vegetation along a section of a few hundred metres, but north and south of that there is no evidence of damage. Where the wave did cross the reef flat and shoreline, the results were removal of all shoreline shrubs (mainly *Scaevola* but with some *Argusia*) and of all young and intermediate-size palms for up to 50 metres inland, but most fully grown trees survived, leaving an untypical vista of palm canopy without undergrowth and a clear view all around. Early visitors to this site reported the presence of a dead shark well inland, as well as some turtles (still alive and thus rescued).

Working northwards through the islands: on Eagle island on the Great Chagos Bank, on the north-eastern shore, there was a remarkable section of several hundred metres where the waves clearly punched 80 - 100 metres inland, stripping away the *Scaevola* bushes and young palms (Fig. 6) removing much of the previously gently sloping beach and leaving a 'step' of 1.5 m high (Fig. 7). When visited two months later, this area had no undergrowth (Fig. 8), but under the canopy of mature palms there were numerous newly sprouting coconuts. This shoreline damage, uniquely in this archipelago, continued around the northern tip and down the north-western facing side for some hundreds of metres too, illustrating the complicated refraction patterns of the waves. On North Brother, the little landing beach has been drastically changed and enlarged (Fig. 9) and the rim is now more narrow than previously. The entire eastern half of this island was clearly affected. The ground nesting Brown Booby colony which has been observed there since at least 1975 was almost certainly washed over, but the colony as a whole has survived. There were no young boobies or chicks in February



Figure 6. Section of the coast of NE Eagle Island where shoreline shrubs and 'undergrowth' have been removed by the tsunami. Breaking water marks the edge of the reef flat. This side of Eagle Island faces East, into the huge lagoon of the Great Chagos Bank.



Figure 7. Observer providing scale to the 1.5 m step formed from eroded and undercut land, at the same site as Figure 6.



Figure 8. East Eagle Island where all undergrowth was removed, including young palms and *Scaevola*. The ground vegetation here (2 months later) is only of newly sprouted coconuts. This is the same site as Figure 6. The affected section of Diego Garcia has an identical appearance.



Figure 9. North Brother's thinning rim near the landing beach, facing approximately east. Shoreline shrubs are missing.

2005, only mature, fully fledged adults and eggs, meaning that there was a gap in the usual demographic pattern, as at that time of year many chicks and young would have been expected too. The western side of the island was still filled with burrows of shearwaters, many occupied.

Middle Brother was packed with uncounted numbers of terns including young and fledglings, and although there was an indefinable change to the shoreline in the area where it is possible to land, this island appeared to be unaffected. The tiny Resurgent island obviously did not suffer a washover despite its small size and exposed location: it had retained its small but healthy colony of adult masked boobies, with young adults and chicks as well as eggs. South Brother had areas of its shoreline shrubs removed in its south-eastern end in manner similar to elsewhere. Nelson island was unaffected and remained packed with birds.

In Salomon atoll, observations of all shores and a walk around Ile Boddam showed substantial erosion of the seaward shores with 'steps' everywhere of 1-2 m high. Yacht-based visitors reported that several turtle nests on these shores had their eggs exposed, to be eaten by hermit crabs and, presumably, by the rats. Sand banks were shifted, and much sand was pumped into the lagoon. Sand shifts around these islands seasonally, and it appears that the result of the tsunami was an acceleration and exaggeration of this process. In Salomon there were no areas of stripped vegetation.

The degree of erosion is impossible to accurately assess given that there were no fixed markers against which to measure change. The North end of Ile de Coin, however, was examined in a little more detail in the late 1970s. The fact that erosion there is proceeding markedly has been remarked on and illustrated well before the tsunami (Sheppard 2002). The changes seen this time, three years after that last visit, have accelerated considerably. The rim of the island there now appears reduced, and appears to have gone completely in places; sand and vegetation form the outer edge of the island at this point. That erosion is increasing here is obvious, but it can only be guessed how much of that is due to the tsunami and how much to the many storms and high tides since the previous visit three years ago.

Sites in these atolls not mentioned above appeared not to have been affected to a noticeable degree.

Sublittoral Observations

In the sublittoral, the reefs were inspected by snorkelling at all the above sites, as well as on east and west sides of Diego Garcia and Salomon atolls, and on the east side of Eagle Island (Great Chagos Bank), West Peros Banhos and in North-East Egmont. The results must be set against the observation, noted above, that coral mortality was very heavy following the 1998 warming, when over 90% of corals were killed to at least 10 and sometimes 30 m deep (Sheppard, 1999). Broadly, while western facing sites which had shown some recovery in 2002 showed much more recovery in 2005 (Fig. 10), those eastern facing sites which had shown almost no recovery in 2002 still showed little recovery.



Figure 10. Underwater off Salomon atoll's Ile Anglais, located on the western side of the atoll, facing West, at the drop-off at 8 m depth. This seaward reef shows young and vigorous growth of table corals.

This pattern was not universal, however: the side of Nelson Island facing Sumatra was seen to be recovering well with good cover of tabular *Acropora* corals (Fig. 11), and similarly, the eastern side of Eagle island off the section where vegetation was stripped away, coral recovery was modest, but included many branching species which remained undamaged (Fig. 12). In eastern Diego Garcia, considerable coral rubble was seen in some eastern seaward locations, but not in others. In all sites, the limited recovery of coral cover that had occurred included healthy colonies of relatively fragile species.

While it might be tempting to conclude that the very low coral cover on eastern



Figure 11. North-eastern end of Nelson Island, Great Chagos Bank, showing young and vigorous growth of table corals. The drop-off here is 6 m depth.

sides could be attributable to tsunami damage, the fact remains that these same sites showed limited or no recovery from the 1998 mortality in 2002 either. Thus caution in interpretation is needed. Another important point is that the eastern sides, exposed to the Southeast Trades, used to be (in 1996) dominated more by soft corals than by hard corals, and the soft coral assemblages at that time were distributable along a 'stress gradient', such that the south-eastern slope of Salomon visited here supported "Rich *Simularia* & *Lobophytum* coverage on upper slope" in 1996 (see Reinicke and Van Ofwegen, 1999). While recovery in some areas has been strong with respect to hard corals, soft coral recovery has been extremely poor everywhere in Chagos that has been examined to date. For unexplained reasons, soft coral recruitment has lagged well behind that of stony corals. The possibility exists therefore that it is this widespread lack of soft coral recovery in sites which had been dominated by them before 1998, that causes eastern



Figure 12. Eagle Island, eastern or lagoon-facing slope, 7 m depth, offshore from the most heavily affected shoreline. This site is located beneath where Figure 6 was taken. Much of this substrate is covered with *Heliopora*.

sites to remain depauperate compared with western sites. The present information cannot resolve this question. This has been examined more during early 2006, though results are not yet available.

DISCUSSION

These atolls, like many areas in the Maldives, were not impacted nearly as badly as many continental locations. Where there were effects, such as stripped vegetation, this may be due to undefined local bathymetric or funnelling effects, but nowhere did the damage caused by this extend over more than a few hundred metres of shoreline. Numerous reasons have been posted on the internet about supposed effects in Chagos and in Diego Garcia in particular, ranging from the timely raising of submerged barriers to protect the infrastructure on Diego Garcia, to the assertion that the islands were, in fact, lost completely but that this was being kept secret for military reasons. The truth, as described above, is perhaps less interesting. One serious suggestion with more widespread currency is that protection came from the existence of a deeper water ‘trench’ just east of the archipelago. However, although there is a deeper ‘trench’ just East of the Chagos Bank, its depth and extent appear to be no greater than many other irregular

features of the eastern Indian Ocean when that region's bathymetry is examined on a broader scale (GEBCO Digital Atlas, 2000, and see Figure 2). Whether depth effects below 2 000 or 3 000 m are important in connection with tsunami energy is not known to this author.

Underwater, the situation is more interesting and remains unresolved. There is less recovery on most eastern facing seaward reefs, but only where these reefs previously were dominated by soft corals killed in 1998. The few sites examined which had substantial stony coral cover in 1996, now supported substantial cover of the same groups of stony corals (up to 40% coral cover in places). This was conspicuous because the dominant stony corals concerned were usually table *Acropora* species. Areas made more or less bare in 1998 which had been more dominated by soft corals remained more or less bare, given the curious lack of soft coral recruitment. Equally interesting is that there is a strong conservatism in the kinds of corals which were recruiting: where once table corals had dominated but been killed in 1998, leaving much bare substrate for several years, the same species were again emerging in strength. Thus although this has greatly confounded any distinction between tsunami effects and selective recruitment patterns, on balance it seems likely that localised differences in proportions of successful stony corals and unsuccessful soft corals is the likeliest explanation of remaining bare areas of sublittoral substrate in this archipelago.

ACKNOWLEDGEMENTS

This visit was made possible by the staff of the British Party on Diego Garcia and of the Fisheries Protection Vessel *Pacific Marlin*, led by Chris Davies and Bob Goodwin, whose help and hard work made the visit a success. I would mention in particular Paul Maynard, Lee Morrison and Nick Mynard, who assisted with my inspections of many miles of shore and many of the reefs, and Nestor Guzman who assisted me in Diego Garcia. My grateful thanks to them all.

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